Firearm-related juvenile death rates correlate with gun ownership rates, measures of guns in circulation and leniency of existing firearm laws among US states

Amanda Tomlinson  
Icahn School of Medicine at Mount Sinai

Megan Paul  
Icahn School of Medicine at Mount Sinai

Ruya Zhang  
Icahn School of Medicine at Mount Sinai

Bian Liu  
Icahn School of Medicine at Mount Sinai

Brian A Coakley (brian.coakley@mountsinai.org)  
Icahn School of Medicine at Mount Sinai  https://orcid.org/0000-0002-3259-6799

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Abstract

Background

In the United States, firearms now rank as the second-leading cause of death among children and adolescents, trailing only motor-vehicle accidents. Prior reports have calculated that 87% of all children aged 0-14 killed by firearms in high-income countries are US children. This study sets out to determine how rates of gun ownership, surrogate markers for the number of guns in circulation and strictness of firearm-related correlated with firearm-related mortality among both juvenile and overall populations at the state level.

Methods

Firearm-associated mortality rates among juveniles, as well as among all ages, were obtained for each US state from the Centers for Disease Control and Prevention (CDC). The number of National Firearms Act weapons and federal firearms licensees for each state was taken from the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF). State-level gun ownership rates, poverty rates and unemployment rates were procured from the RAND corporation, US. Census Bureau and US Department of Labor, respectively. Mental health data was taken from the CDC’s behavioral risk factor surveillance system. Gifford Center Scorecard Rankings were used a relative measure of firearm law strictness. Bivariate linear regression was used to model the relationships between firearm-associated mortality as well as ATF registered weapons, ATF federal firearm licensees, Giffords Center scorecard rankings and gun-ownership rates. Multivariate analysis was then performed to control for state-level differences in poverty rates, unemployment rates and poor mental health.

Results

Unadjusted analysis showed that more ATF federal firearm licensees, higher gun ownership rates and more lenient gun laws were associated with increased rates of firearm-associated mortality among juveniles. Similarly, all 3 such measures as well as more ATF registered weapons were associated with increased rates of firearm-related death among overall populations. In the adjusted analysis, more ATF registered weapons, more ATF federal firearm licensees, higher gun ownership rates and more lenient firearm laws were all associated with higher rates of firearm-related mortality among both juvenile and overall populations.

Conclusions

In order to reduce the risk of firearm-associated death among children, US policy makers and stakeholders should focus on implementing more restrictive firearm laws and decreasing gun ownership rates.

Background
Unintentional injuries currently remain the third-leading cause of death among US residents. Among these unintentional injuries, firearm-related death ranks as the third-most common mechanism, taking the lives of approximately 35,000–40,000 people each year (Centers for Disease Control and Prevention [CDC], 2022). In addition, seven American children die every day as a result of firearm-related injuries, making firearm-related death now the second-leading cause of death of children and adolescents in the US, trailing only motor-vehicle accidents (Cunningham et al. 2018). Further, in the United States, the rates of firearm-related injury, homicide, suicide and accidental death are significantly higher than in other high-income countries (Richardson et al. 2003; Dowd et al. 2020). Prior reports have calculated that among populous, high-income countries, 87% of all children aged 0–14 killed by firearms are US children (Richardson et al. 2011).

Currently, there exists tremendous variation among US states regarding both the types of firearm-related laws employed and the number of firearms per capita. Similarly, there is also widespread variation in the rates of firearm-related injury and death among both the juvenile and overall populations in US states. Previous studies have shown that states with stricter firearm laws and regulations have lower rates of firearm-related injury and death than states with a more lenient environment towards firearms (Fleegler et al. 2013). To that end, Goyal et al showed that universal background checks for the purchase of ammunition and firearms are associated with a lower risk of firearm-related mortality among children (Goyal et al. 2019). Multiple prior studies have investigated the link between several social determinants of health (SDOH) and firearm-associated mortality. Specifically, previous studies have shown that higher income inequality (Johnson et al. 2021; Kim et al. 2019), increased food insecurity (Ali et al. 2022), higher unemployment (Bray et al. 2020), increased poverty (Bray et al. 2020), lower public welfare spending (Kim et al. 2019) and fewer healthcare resources (Choi et al. 2020) are associated with increased rates of firearm-associated mortality.

We set out to determine how surrogate markers for the number of guns in circulation, rates of gun ownership and the relative strictness of firearm-related laws correlated with firearm-related mortality among both juvenile and overall populations at the state level. We also assessed multiple social determinants of health that could also impact rates of gun violence, including the rates of poverty, unemployment and poor mental health at the state level.

**Methods**

We set out to select variables relating to either the number of guns per capita or to the relative strictness of state-level firearm-related legislation. We restricted the data analyzed to only those measures which were available at the state-level and were maintained in publicly-available databases or publications. We extracted data from the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) for the number of ATF federal firearm licensees and number of ATF registered weapons in each state from 1997–2020 (Bureau of Alcohol, Tobacco, Firearms and Explosives 2021). ATF registered weapons data includes registration of all weapons covered by the National Firearms Act. Specifically, the Act covers shotguns and rifles having barrels less than 18 inches in length, certain firearms described as “any other weapons,”
machine guns, and firearm mufflers and silencers (Cornell Law School, 26 US Code § 5849, 2021). A federal firearm license allows individuals to engage in business related to the manufacture of ammunition or firearms or the interstate or intrastate sale of firearms (Cornell Law School, 18 US Code § 921, 2021). State-level gun ownership rates were taken from 2016 data collected by the RAND corporation. The RAND corporation provides estimates of gun ownership at the state level through the use of composite survey data as well as four proxy indicators of gun ownership. These proxy indicators include the proportion of suicides in which a gun is used (from the CDC), the number of hunting licenses per capita (from the U.S. Fish and Wildlife Service), the number of Guns & Ammo magazine subscriptions per 100 residents (from the Alliance for Audited Media), and the number of background checks conducted per ten residents (from the National Instant Criminal Background Check System) (Schell et al. 2020). Gifford Law Center scorecard rankings, a relative measure of the strictness of each state’s gun laws, with lower numbers denoting stricter laws, were also obtained for the year 2020 (Giffords Law Center 2021). Population and poverty data were recorded from the U.S. Census Bureau (U.S. Census Bureau 2021) while unemployment data was collected from the U.S. Department of Labor (US. Department of Labor 2021). Firearm-related age-adjusted mortality rates among juvenile (age \( \leq 18 \) years) and overall populations, the outcomes of interest, were procured from the CDC (CDC Web-based Inquiry Statistics Query and Reporting System 2021). Data on mental health was collected from the CDC’s Behavioral Risk Factor Surveillance System (CDC Behavioral Risk Factor Surveillance System 2021). The prevalence of poor mental health in each state was defined as the percentage of residents stating on the BRFSS that they experienced “poor mental health” for over 14 days of the prior month, as has been done in other studies (Massetti et al. 2017; Steinberg et al. 2015). For several continuous variables, such as firearm-related mortality rates, ATF registered weapons, ATF federal firearm licensees, poverty rates and state-level population, available data from 1997–2018 was averaged to obtain stable estimates at the state level. Statistical analysis was conducted using R software (version 0.4.4).

We used bivariate linear regression to model the relationships between mortality and four previously mentioned continuous measures separately: ATF registered weapons, ATF federal firearm licensees, Giffords Center scorecard rankings and gun-ownership rates. We first ran the unadjusted bivariate model where each of the aforementioned covariates is the only explanatory variable in the model. We then ran a multivariate model where three state-level covariates (poverty rates, unemployment rates and the percentage of population with greater than 14 days of poor mental health of the prior month) were controlled for simultaneously along with each measures of guns-in-circulation, state gun ownership rates and relative strictness of state-level firearm laws. A predetermined threshold of \( p < 0.05 \) was deemed significant and all analyses were run in R Studio software, version 1.4.1717.

**Results**

Descriptive statistics are displayed in Table 1. Among all 50 US states, average juvenile firearm-related mortality rates varied widely, with the highest being 6.98 per 100,000 (Alaska) and the lowest being 0.37 per 100,000 (Hawaii). Similarly, there was also wide variation in firearm-related mortality rates across all age groups, with the highest being Louisiana (19.63 per 100,000) and the lowest being Hawaii (3.37 per
100,000 population). Gun-ownership rates among adults varied widely, with the highest rate being in Montana (63.41%) and the lowest rate being in Hawaii (9.78%). Based on Giffords Law Center state rankings, California was deemed to have the nation’s strictest firearm laws, while Mississippi’s were regarded as the most lenient (Giffords Law Center 2021). The highest numbers of ATF registered weapons (3029.12 per 100,000 residents) and ATF federal firearm licensees (28.89 per 100,000 residents), were found in Wyoming and Montana, respectively. Conversely, the lowest numbers of ATF registered weapons (56.47 per 100,000 residents) and ATF federal firearm licensees (0.99 per 100,000 residents) were observed in New York and New Jersey, respectively. Poverty rates were lowest in New Hampshire (8.7%) and highest in Mississippi (22.28%), while poor mental health was most common in West Virginia (14.79%) and least common in North Dakota (6.71%).

First, in the unadjusted bivariate model for people under 18 years-old, firearm-related mortality in children was found to positively correlate with higher Giffords Center scorecard rankings, increased ATF federal firearm licensees, and higher gun ownership rates (all \( P < 0.01 \), See Table 2). In the unadjusted bivariate model for people of all ages, firearm-related mortality was found to positively correlate with higher Giffords Center scorecard rankings, increased ATF federal firearm licensees, increased ATF registered weapons, and higher gun ownership rates (all \( p < 0.05 \), See Table 2). The only covariate that was significantly associated with firearm-related mortality in children under 18 years-old was poverty (\( p < 0.01 \)). In people of all ages, both poverty and poor mental health were significantly associated with firearm-related mortality (both \( p < 0.01 \)).

In the multivariate model that controlled for poverty, poor mental health, and unemployment across states, higher Giffords scorecard ranking, increased ATF federal firearm licensees, increased ATF registered weapons, and higher gun ownership rates were significantly associated with increased firearm-related mortality in children under 18 years-old (all \( p < 0.02 \), see Table 3). In the same multivariate model for people of all ages, higher Giffords scorecard ranking, increased ATF federal firearm licensees, increased ATF registered weapons, and higher gun ownership rates were significantly associated with increased firearm-related mortality (all \( p < 0.01 \), See Table 3).

**Discussion**

Despite the relatively high rate of gun-related juvenile deaths in the US, and the growing nature of this problem (Lee et al. 2019), this association between gun policies and gun deaths among children and adolescents remains relatively understudied. In 2019, Zeoli et al. conducted a scoping review on this topic, but found only 20 studies from 1985–2018 analyzing the impact of firearm policies on gun-related outcomes among juvenile populations (Zeoli et al. 2019). The relative paucity of data on this subject is likely attributable to multiple causes, but a lack of funding has been pinpointed by several studies (Jagger et al. 1986; Stark et al. 2017; Kellermann et al. 2013). A 2017 report in the *Journal of the American Medical Association* showed that gun violence received 1.6% of the funding predicted ($1.4 billion predicted, $22 million observed) based on the observed mortality rate (Stark et al. 2017). To some degree, this lack of funding is by design. In 1996, pro-firearm members of the US House of
Representatives were able to insert the following text into an Omnibus Consolidated Appropriations Bill, “none of the funds made available for injury prevention and control at the Centers for Disease Control and Prevention may be used to advocate or promote gun control.” (US Government Publishing Office, Omnibus Consolidated Appropriations Bill. HR 3610, 1996). Further, a 2009 study funded by the National Institute on Alcohol Abuse and Alcoholism found that individuals carrying a gun were significantly more likely to be shot in an assault than were individuals who were not in possession of a firearm (Branas et al. 2009). Two years after that study was published, Congress expanded the same restrictive language employed in the 1996 appropriations package to apply to all Department of Health and Human Service agencies, including the National Institutes of Health (US Government Publishing Office, Consolidated Appropriations Act 2012, 2021).

We found that states with higher numerical Giffords Center scorecard rankings, and thus more lenient firearm laws, had higher age-adjusted firearm-related mortality rates. In addition, we similarly observed that states with higher rates of gun ownership among their adult populations also had higher levels of age-adjusted firearm-related mortality. Further, the adjusted model found that increased numbers of ATF registered weapons and ATF federal firearm licensees were significant predictor of increased firearm-related death among juveniles and overall population, even when controlling for poverty, poor mental health and unemployment. To our knowledge, the associations between ATF registered weapons, ATF federal firearm licensees and Giffords Law Center scorecard rankings with rates of firearm-related deaths among children are novel and have not previously been reported. However, Reeping et al. did show associations between multiple scales of gun law permissiveness, including Giffords scorecards rankings, and rates of firearm-related deaths among overall state-level populations (Reeping et al. 2021).

Although the Giffords Center Ranking reflects the relative stringency of each state’s overall set of gun laws, other studies have repeatedly shown associations between the addition of more restrictive gun laws and decreased risks of gun-related death among juvenile (Goyal et al. 2019; Webster et al. 2004; Webster et al. 2000; Safavi et al. 2014; Hepburn et al. 2006; Madhavan et al. 2019) and overall populations (Kalesan et al. 2016; Santaella-Tenorio et al. 2016; Gunn et al. 2021; Schell et al. 2020, Siegel et al. 2019). Due in large part to such evidence, the most recent position statements of both the American Academy of Pediatrics (AAP) (Dowd et al. 2012) and the American Pediatric Surgical Association (Petty et al. 2019) call for a host of gun-related laws and regulations, including child access safety laws, trigger locks and safe storage requirements, universal background checks, ending the gun show/private sale loophole, banning assault weapon purchase and ending barriers that block firearm-related research. In addition, the AAP’s position statement also calls for investigating illegal gun sales to minors, regulating the manufacture and importation of certain classes of guns and instituting mandatory waiting periods.

The National Firearms Act (NFA) of 1934 established that several classes of weapons need to be registered with the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) (Cornell Law School 26 US Code Chap. 53, “National Firearms Act 1934”, 2021). These classes have been modified over time, but still include certain shotguns, weapons made from shotguns, short barrel rifles, machine guns, silencers, destructive devices and certain types of concealed weapons (Bureau of Alcohol Tobacco, Firearms and
Explosives 2021) weapons correlated with increased risk of firearm-related deaths among juveniles. Further, higher levels of gun ownership correlated with increased rates of firearm-related deaths among juveniles in the unadjusted model and continued to be a significant predictor of firearm-related juvenile death in the adjusted model. This data confirms one of the first known associations between how increasing numbers of guns in circulation result in higher rates of firearm-related deaths among US juvenile populations. Similarly, the relationship between gun ownership and the risk of firearm-related death among overall state populations has been previously demonstrated (Lurie et al. 2015). In 2016, a similar association between gun ownership and firearm-related suicide rates among US adults was reported (Siegel et al. 2016). Due in part to this association, the AAP's 2012 position statement, which was reaffirmed in 2016, states that “The AAP affirms that the most effective measure to prevent suicide, homicide and unintentional injuries to children and adolescents is the absence of guns from homes and communities” (Dowd et al. 2012).

Many have explored the effect that mental health can have on rates of firearm-related injury and death, mostly focusing on suicide (Swanson et al. 2020; Dowd et al. 2020; Goldstein et al. 2019; Miller et al. 2013). However, the exact influence that poor mental health exerts on the prevalence of gun violence remains unclear. A 2020 report by Dowd and colleagues found that only one-third of self-inflicted firearm injuries in the United States is associated with a pre-existing behavioral health condition (Dowd et al. 2020). Further a recent report by the National Council for Behavioral Health estimated that persons with serious mental illness were responsible for fewer than 4% of all violent acts in the U.S. (National Council for Mental Wellbeing 2019). In 2013, Ferrari and colleagues found that many countries have higher rates of mental illnesses, such as major depressive disorder, than the United States (Ferrari et al. 2013) while simultaneously maintaining dramatically lower rates of firearm-related mortality (Richardson et al. 2011; Dowd et al. 2012). Similarly, poor mental health was found to be associated with an increased risk of firearm-related mortality for overall populations, but not for juvenile populations, in the present study.

This study does have several limitations. Not all firearms are subject to the NFA and, thus, tracked by the ATF. For example, pistols or revolvers having rifled bores are not regulated by the NFA and, therefore, are not captured in the ATF registered weapons statistics. In practicality, the vast majority of handguns, which have been shown to cause 47% of homicides (Federal Bureau of Investigation 2017) and 70% of suicides (Nestadt et al. 2020; Wintemute et al. 1988), are excluded from the NFA. Thus, the number of ATF registered weapons is not a comprehensive measure of the number of publicly-owned guns. Further, as an ecological study, we can only demonstrate associations, rather than direct causation. Thus, while our findings that more lenient gun laws and higher rates of gun ownership positively correlate with increased rates of firearm-related mortality amongst juveniles are significant, they cannot specify that these factors were clearly causative. While we used the Giffords Center Ranking as a relative measure of gun law stringency, this measure does not allow for a more nuanced assessment of how much more restrictive one state's firearm laws are to another. Finally, some have argued that at least one of the proxy measures of gun ownership employed by the RAND corporation, the proportion of suicides committed with a firearm, is biased and show not be used to help estimate state-level gun ownership rates (Gomez et al. 2020).
Conclusions

This study provides evidence indicating that stronger firearm laws, fewer ATF registered weapons, fewer ATF federal firearm licensees and fewer firearms-in-circulation, are associated with decreased rates of firearm-related death among juvenile and overall populations at the state level. Thus, policy makers should focus on both enacting more restrictive firearm laws and decreasing the rates of gun ownership in order to reduce rates of firearm-related deaths among children.

Abbreviations

Centers for Disease Control and Prevention (CDC); The Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF); behavioral risk factor surveillance system (BRFSS); National Firearms Act (NFA)

Declarations

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Conflict of Interest: None

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Consent for publication: Not applicable

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Competing interests: The authors declare that they have no competing interests.

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Author’s contributions: AT helped design the study, acquired study data, performed data analysis, interpreted analysis findings and wrote the manuscript. MP acquired study data, performed data analysis and wrote portions of the manuscript. RZ and BL performed data analysis and wrote portions of the manuscript. BC designed the study, acquired study data, interpreted analysis findings and wrote the manuscript. All authors approved the submitted version of the manuscript and agree to be personally accountable for their own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

Acknowledgements: Not applicable
References


Tables

Table 1 is available in the Supplementary Files section.

Table 2

Title: Unadjusted Analysis for Firearm-Related Mortality

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<th>Variable</th>
<th>Children Under 18 years-old</th>
<th>All Ages</th>
</tr>
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<td>ATF registered weapons</td>
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<td>3.23E-03 0.026</td>
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<td>ATF federal firearm licensees</td>
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<td>Gun-ownership rates</td>
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<td>Giffords Center scorecard rankings</td>
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Covariates:

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<td>Unemployment</td>
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**Detailed Legend:** Unadjusted Bivariate Analysis of Firearm-Related Mortality for Children under 18 years-old and people of all ages. The slope of the linear regression (Beta) and the associated p value are included. Bold values are those that were associated with a threshold of p<0.05

Table 3

Title: Adjusted Multivariate Analysis for Firearm-Related Mortality
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<th>P Value</th>
<th>Beta</th>
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**Detailed Legend:** Adjusted Multivariate Analysis of Firearm-Related Mortality for Children under 18 years-old and people of all ages after controlling for poverty, poor mental health, and unemployment. The slope of the linear regression (Beta) and the associated p value are included. Bolded values are those that were significantly associated with a threshold of p<0.05

**Supplementary Files**

This is a list of supplementary files associated with this preprint. Click to download.

- [Table1.xlsx](#)